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Research Paper

MECHANICAL PROPERTIES OF CARBON/GLASS FIBER REINFORCED EPOXY HYBRID POLYMER COMPOSITES

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Hybrid composite materials are the great potential for engineering material in many applications. Hybrid polymer composite material offers the designer to obtain the required properties in a controlled considerable extent by the choice of fibers and matrix. The properties are tailored in the material by selecting different kinds of fiber incorporated in the same resin matrix. In the present investigation, the mechanical properties of carbon and glass fibers reinforced epoxy hybrid composite were studied. The vacuum bagging technique was adopted for the fabrication of hybrid composite materials. The mechanical properties such as hardness, tensile strength, tensile modulus, ductility, and peak load of the hybrid composites were determined as per ASTM standards. The mechanical properties were improved as the fibers reinforcement content increased in the matrix material.

Keywords: BHN, Epoxy, Hybrid composite, Carbon/Glass fiber, Tensile strength

INTRODUCTION

Now a days, the composite engineers are focusing on the development of new stronger, tougher, lightweight structural materials supporting latest technologies and design concepts for the complex shaped structures like aircraft, automotive structures and large wind turbine blade structures (Gururaja *et al.*, 2012). The development of composite materials improves their performance based on the reinforcement of two or more fibers in a single polymeric matrix, which leads to the advanced material system called hybrid composites with a great diversity of material properties (Prabhakaran *et al.*, 2012). This is a major challenge that can only be met through an understanding of the relationships between materials architecture and mechanical response. The positive or negative hybrid effect of selected mechanical property from the rule of mixture behavior of carbon/carbon/epoxy and glass/carbon composites were

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studied. None of the mechanical properties, excluding the fracture energies show signs of a positive hybrid effect (Marom *et al.*, 1978). Manders and Bader (1981) reported hybrid effect and failure strain enhancement of up to 50% for the glass fiber/carbon fiber/epoxy composite. The failure strain of the carbon phase increased as the relative proportion of carbon fiber was decreases and as the carbon fibers were more finely dispersed. Yerramalli and Waas (2003) have considered carbon/glass hybrid composite with an overall fiber volume fraction of 30%. Splitting and kinking failures were noted while loading the hybrid laminates under static and dynamic loading rates. Zhang *et al.* (2012) studied the mechanical behavior of hybrid composites made of carbon/glass reinforcements and the processing method used is 'wet lay-up' which is not a best practice for obtaining high quality laminates. An addition of hard reinforcements such as silicon carbide, alumina and titanium carbide improves hardness, strength and wear resistance of the composites (Amar Patnaik *et al.*, 2009; and Chauhan *et al.*, 2009). The introduction of a glass fiber into a polymer matrix produces a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained with monolithic alloys (Schwartz, 1984). Among the various useful polymer matrices, vinyl ester is typically characterized by properties such as fluidity, corrosion resistance and high strength-weight ratio (Suresha *et al.*, 2007). The advantages of Fiber-reinforced PMCs over traditional materials include greater mechanical strength, lighter weight, better dimensional stability, higher dielectric strength and corrosion resistance and flexibility to improve the designs (Folkes, 1992). The effectiveness of reinforcement essentially depends on the adhesion between matrix and fiber, so this is a key factor in determining the final properties of the composite material, particularly its mechanical properties (Yosoyima *et al.*, 1984; Yosoyima *et al.*, 1990; and Pukzky *et al.*, 1995). In the present work, an attempt has been made to study the influence of glass fiber and carbon fiber reinforced epoxy polymer matrix on the mechanical properties. The hybrid composites were developed by varying the reinforcements from 15%, 30%, 45% and 60% of glass fiber and carbon fiber in 40% epoxy matrix under vacuum bag process. The hardness and tensile properties were studied as per the ASTM standards.

EXPERIMENTAL DETAILS

Material Selection

The E-glass fiber and Carbon fibers are selected as reinforcements and Epoxy as matrix material. The epoxy resin and hardener Tri Ethylene Tetra Amine (TETA) were provided by Atul Ltd. Polymers division, Valsad, Gujarat, India. The Glass Fiber of bi-directional woven mat with 200 gsm and the density of 2.5 gm/cc. The Carbon Fiber of bi-directional woven mat with 200 gsm and the density of 1.78 gm/

Figure 1: The Glass Fiber and Carbon Fiber

cc were used. The glass fiber and carbon fiber used in the fabrication of hybrid fiber reinforced composites are shown in Figure 1.

Fabrication of Composites

The Glass/Carbon fiber/Epoxy based hybrid composites were developed using vacuum bag process by varying both the reinforcements in terms of weight percentage of 15%, 30%, 45% and 60% of glass fiber and carbon fiber in 40% of Epoxy matrix. The weight fraction of fibers and epoxy matrix materials were determined by considering the density, specific gravity and mass. Initially, the fabrication of the composite was done at room temperature by hand lay-up technique. The required ingredients of resin and hardener were mixed thoroughly in a basin and the mixture is subsequently stirred constantly. The required sizes of fiber mats were prepared and the glass fiber was positioned manually in the open mold and the mold surface must be smooth enough to prevent bonding to the laminate. The mixture so made is brushed uniformly over the glass and carbon plies alternatively. The entrapped air is removed manually with squeezes or rollers to complete the laminates structure. Then the vacuum bagging is applied to the mold with a vacuum pressure 0.1 m bar for uniform distribution of resin and also to remove the entrapped air. The composite is cured at room temperature and the post curing was done at 50 °C for 30 min, 65 °C for 45 min and 75 °C for 1 hour. The Fiber reinforced PMCs is mainly used due to easy availability of glass fibers and economic processing technique adopted for producing the Fiber-reinforced PMCs. The vacuum bagging process adopted for the development of hybrid composite is shown in Figure 2.

Figure 2: Vacuum Bag Process

Specimen Preparation

The glass fiber and carbon fibers reinforced epoxy composite slabs were taken out from the mold and then specimens of suitable dimensions were prepared from the composite slabs for different mechanical tests according to ASTM standards. The test specimens were cut by slabs by using diamond tipped cutter and different tools in the work shop. Tensile test specimens were prepared according to ASTM D638. Test specimens having dimension of length 60 mm, width of 12 mm and thickness of 3 mm. Micro hardness test specimens were prepared according ASTM standard. Three identical test specimens were prepared for different test.

Testing of FRP Composites

Mechanical properties of composites were evaluated by tensile and hardness measurements. The specimens were prepared from the developed composites and edges of the specimen are finished by using file and emery paper for tensile testing. Tensile tests were examined according to ASTM D638. The specimen was loaded between two manually adjustable grips of a 60 KN computerized Universal Testing Machine (UTM) with an electronic extensometer and the surrounding temperature is 35 °C. A tensile test specimen placing in the testing machine and load was applied until it fractures. Due to the application of load, the elongation and maximum load of the specimen is recorded. Test was repeated thrice and the average value was taken to calculate the tensile strength of the composites. Micro hardness test was conducted as per ASTM standard on the specimen using a Vickers micro hardness tester. The hardness was measured at three different locations of the specimen and the average value was calculated.

RESULTS AND DISCUSSION

Hardness

Hardness is described as resistance to surface indentation of the material. The variations of micro hardness of the composite materials are shown in the Figure 3. This graph explains the effect of glass fiber and carbon fiber reinforcements on the micro hardness of the hybrid composites. The carbon fiber reinforced epoxy composite exhibits higher micro hardness as compared to other two composites. The 60% carbon fiber reinforced composites shows 14.29% increase in the micro hardness as compared to 60% glass fiber reinforced composites and 23% increase in the micro hardness with that of 30% glass fiber and 30% carbon fiber reinforced hybrid composite. The increase in the hardness in the composites is the indication of good bonding between the matrix and the reinforcement materials.

Tensile Strength

Figure 4 shows the effect of reinforcement on Ultimate Tensile Strength (UTS) of the fiber reinforced composites. The ultimate tensile strength of the carbon reinforced composite was higher as compared to other type of composites. The 60% carbon fiber reinforced composites shows 65.24% increase in the UTS as compared to 60% glass fiber reinforced composites and 38.01% increase in the UTS with that of 30% glass fiber and 30% carbon reinforced hybrid composite. The UTS of carbon fiber reinforced composite is higher because the strength of carbon fiber is higher and it behaves like elastic material during tensile loading. The inclusion of carbon fiber mat reinforced polymeric composite

Figure 3: Effect of Reinforcements on Micro Hardness of the Fibers Reinforced Composites

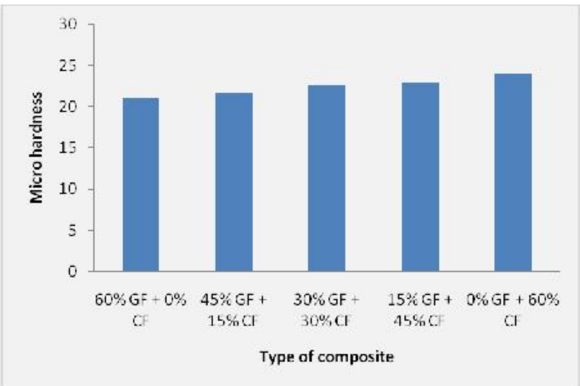
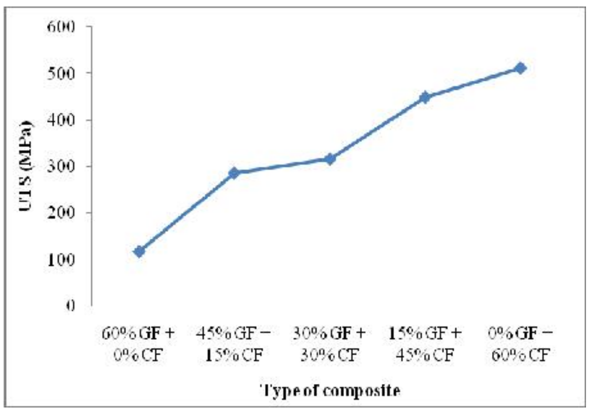


Figure 4: Effect of Reinforcements on UTS of the Fibers Reinforced Composites

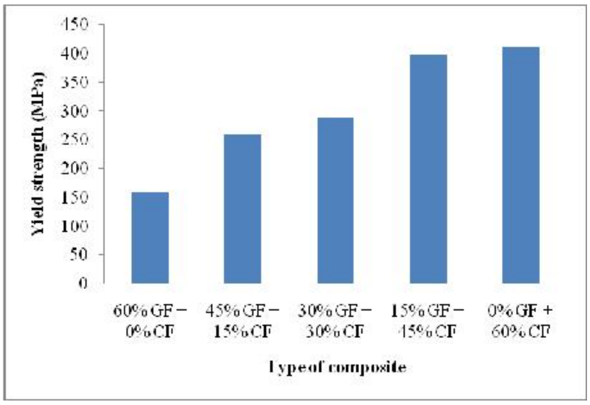


significantly enhanced the ultimate tensile strength of the composite.

Yield Strength

The yield strength of the glass fiber and carbon fiber reinforced epoxy composites depends upon the strength and modulus of the fibers, strength, and chemical stability of the matrix, fiber matrix interaction, and fiber length. The 60% carbon fiber reinforced composites shows 61.31% increase in the yield strength as compared to 60% glass fiber reinforced composites and 30% increase in the yield strength with that of 30% glass fiber and 30% carbon reinforced hybrid composite. Figure 5 shows the effect of reinforcements on yield strength of the fibers reinforced composites. Yield strength increases with increase in addition of reinforcement to composites this may be due to improved in interfacial bonding strength between filler, matrix, and fiber.

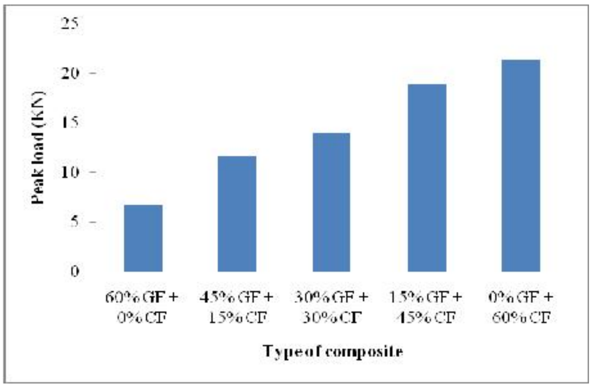
Figure 5: Effect of Reinforcements on Yield Strength of the Fibers Reinforced Composites



Peak Load

Figure 6 shows the effect of reinforcements on peak load of the fibers reinforced hybrid composites. The 60% carbon fiber reinforced composites shows 68.52% increase in the peak load withstand capability as compared to 60% glass fiber reinforced composites and 35% increase in the peak load withstand capability with that of 30% glass fiber and 30% carbon reinforced hybrid composite. The hybrid composite shows more peak load withstand capability as the carbon fiber reinforcement percentage increases in the hybrid composite.

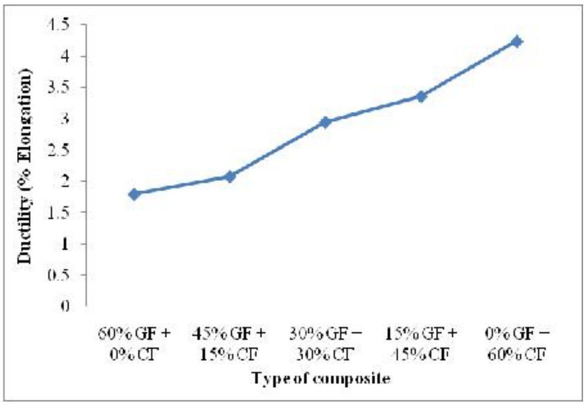
Figure 6: Effect of Reinforcements on Peak Load of the Fibers Reinforced Composites



Ductility

The variation of ductility of fiber reinforced composites is shown in Figure 5. The ductility

Figure 7: Effect of Reinforcements on Ductility of the Fibers Reinforced Composites



of 30% glass fiber and 30% carbon reinforced hybrid composite is lower as compared to other two composites. The 60% carbon fiber reinforced composites shows 26.19% increase in the ductility as compared to 60% glass fiber reinforced composites and 50.94% increase in the ductility with that of 30% glass fiber and 30% carbon reinforced hybrid composite.

CONCLUSION

The carbon fiber and glass fiber reinforced hybrid composites have been fabricated by vacuum bag method. Experimental evaluation of mechanical properties like micro hardness, tensile and flexural strength of hybrid composites as per ASTM standards has been successfully completed. The micro hardness of carbon fiber reinforced composite is higher than the other composites. The tensile properties have been studied and the breaking load has been measured. The inclusion of carbon fiber mat reinforced polymeric composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite. The ductility of carbon fiber reinforced composite is higher than the other composites.

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